Proton Economics

Eric Prebys
FNAL Accelerator Division

Proton Team ("Finley Report")

- Group formed in early 2003 to study proton demands and needs for the "near" future (through ~2012 or so), in the absence of a proton driver.
- Work culminated in a report to the director, available at www.fnal.gov/directorate/program_planning/studies/ProtonReport.pdf
- No big surprises [see P. Kasper "Getting Protons to NuMI (It's a worry)", FNAL Beams-doc-1036, 2001].
- This work will form the basis of "The Proton Plan".

General Comments

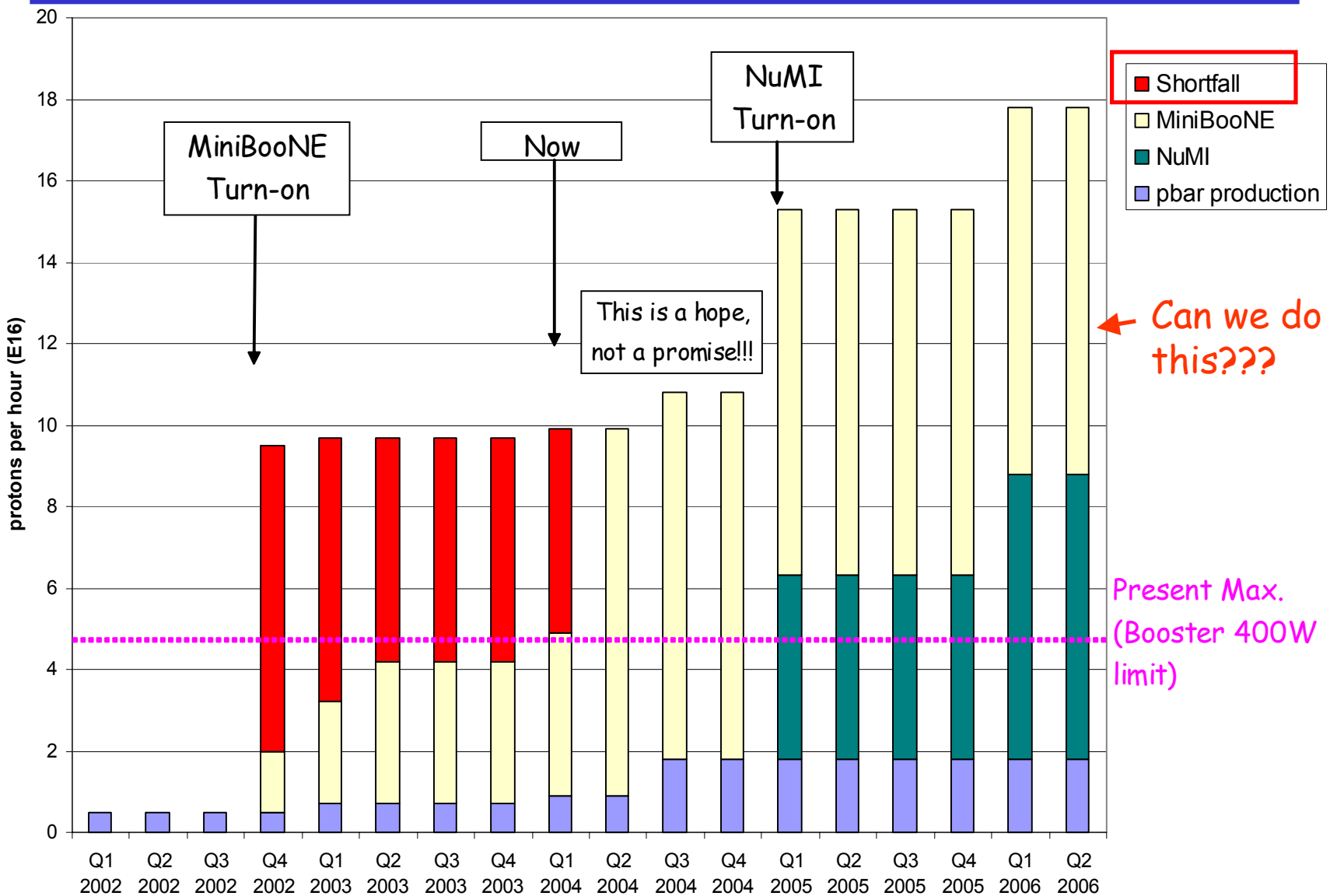
- The linac is not currently a performance bottleneck for the complex *when it is running stably.*
- There are ongoing longevity and reliability concerns in the linac
  - General state of instrumentation is inadequate to characterize linac behavior
  - The 7835 tubes from Burle continue to be a major concern, although the situation is better than it was a year ago.
  - There are new worries about the klystrons, which we formerly believed were not an issue.
  - There are some other longevity issues, if we expect the linac to last another ~10 years.

What Limits Total Proton Intensity?

- Maximum number of Protons the Booster can stably accelerate: 5E12
- Maximum average Booster rep. Rate: currently 7.5 Hz, may have to go to 10 Hz for NuMI+ *(full)* MiniBooNE
- (NUMI only) Maximum number of booster batches the Main Injector can hold: currently 6 *in principle*, possibly go to 11 with fancy loading schemes in the future
- (NUMI only) Minimum Main Injector ramp cycle time (NUMI only): 1.4s+loading time (at least 1/15s* *nbatches*)
- Losses in the Booster:
  - Above ground radiation
  - Damage and/or activation of tunnel components

Our biggest worry at the moment!!!!

Proton Demand

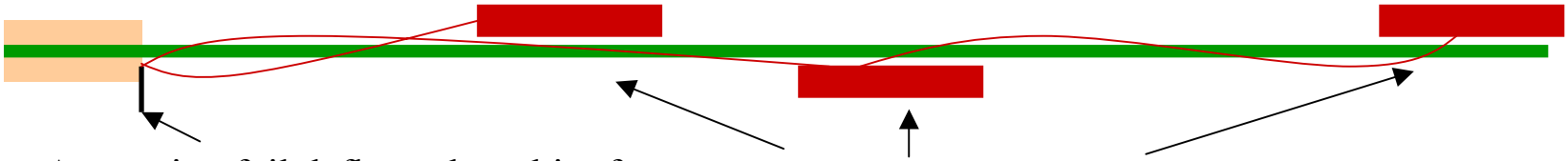


Projects in 2003 (a short list)

- 2003 Activities centered around preparation for the September shutdown:
  - Linac water system upgrade
  - New Linac Lambertson
    - Better optics in 400 MeV line
  - Booster two-stage collimation system
    - In the works a long time
    - Now in place.
  - Major modifications at main extraction region
    - Address "dogleg problem" caused by extraction chicane system.
  - New, large aperture magnets in extraction line:
    - Should reduce above-ground losses
  - Major vacuum system upgrade.
  - Lots of smaller jobs.

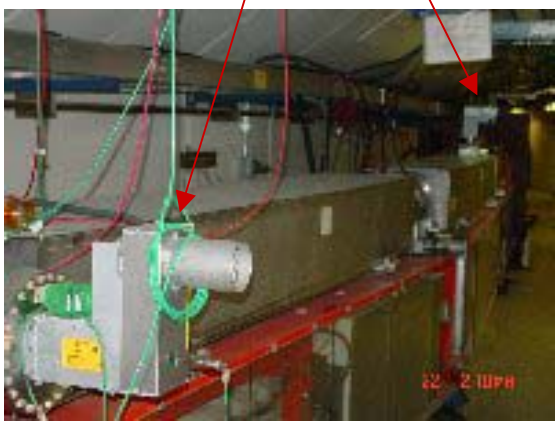
New Collimator System

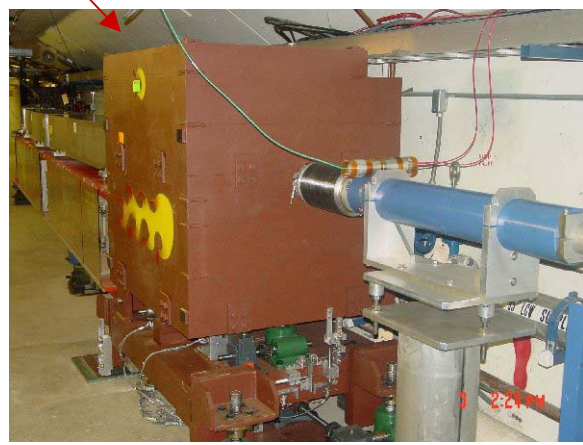
Basic Idea…



A scraping foil deflects the orbit of halo particles…

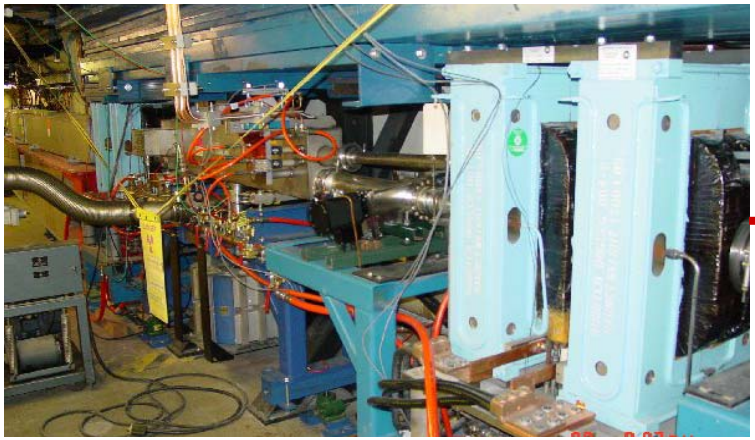
…and they are absorbed by thick collimators in the next periods.

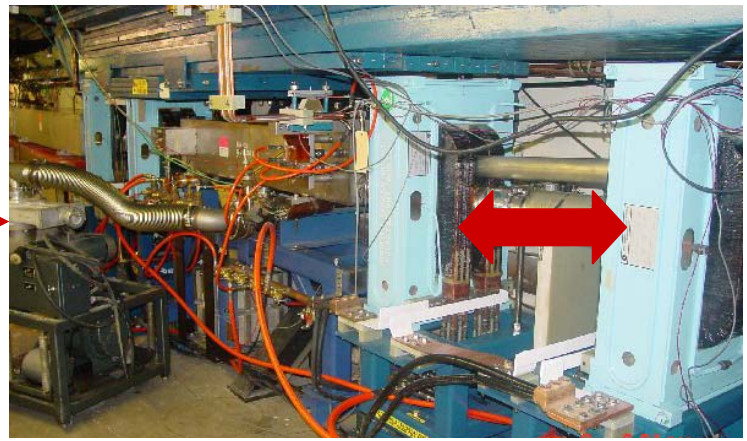


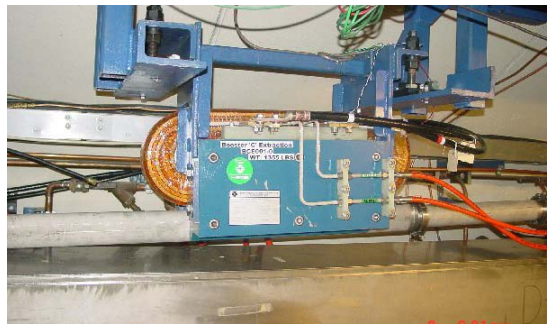


- Should dramatically reduce uncontrolled losses

Long 3 Dogleg Work



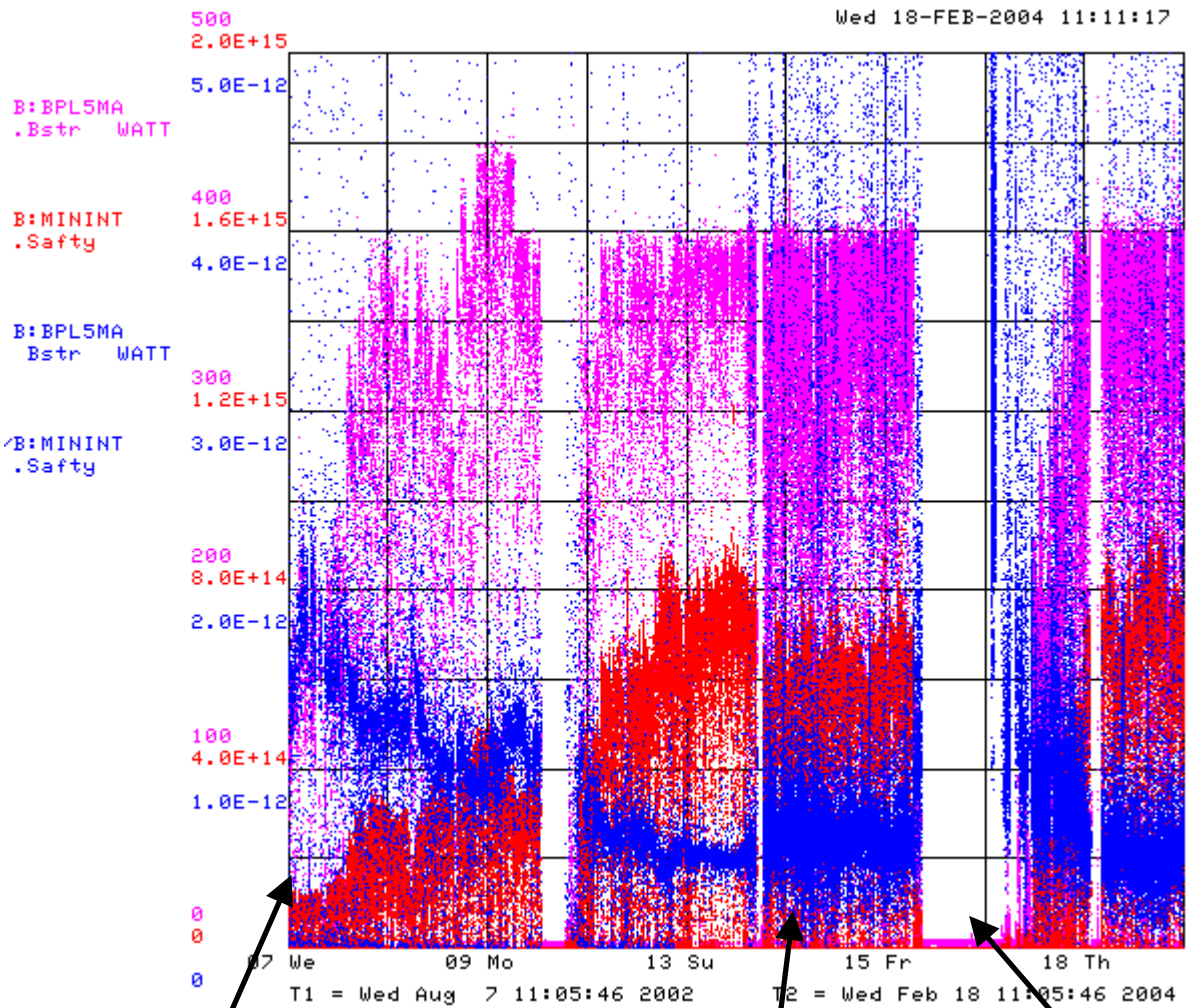




New magnet to match extraction line

- Increase spacing between dogleg pairs from 18" to 40" to reduce lattice distortions at injection.

How are We Doing?



Power loss (W)

Protons (p/min)

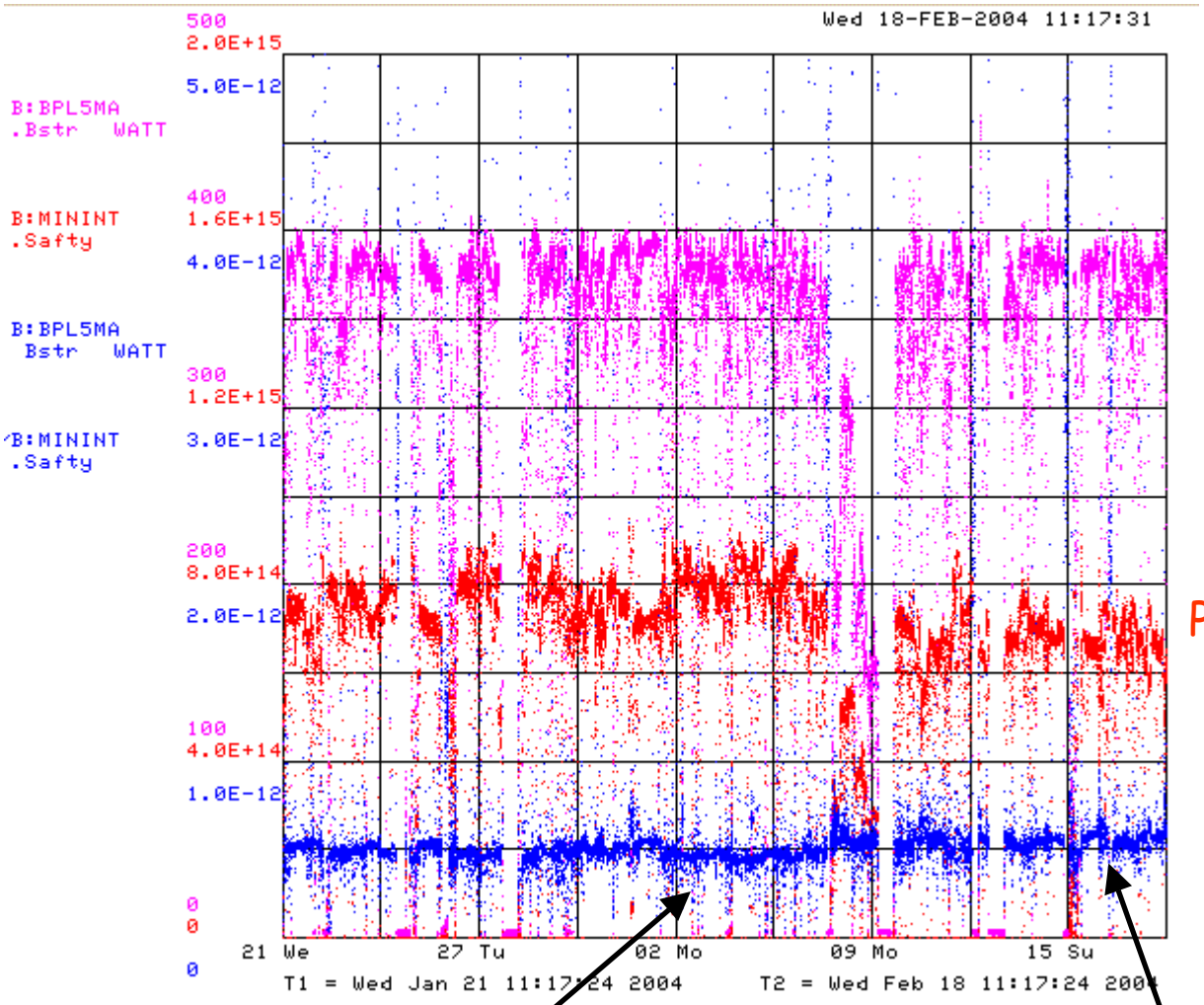
Energy Lost (W-min/p)

BooNE turn-on (Sept. 2002)

"Mysterious" Performance Problems

Big Shutdown

Recent Running (Last 4 Weeks)



Power loss (W)

Protons (p/min)

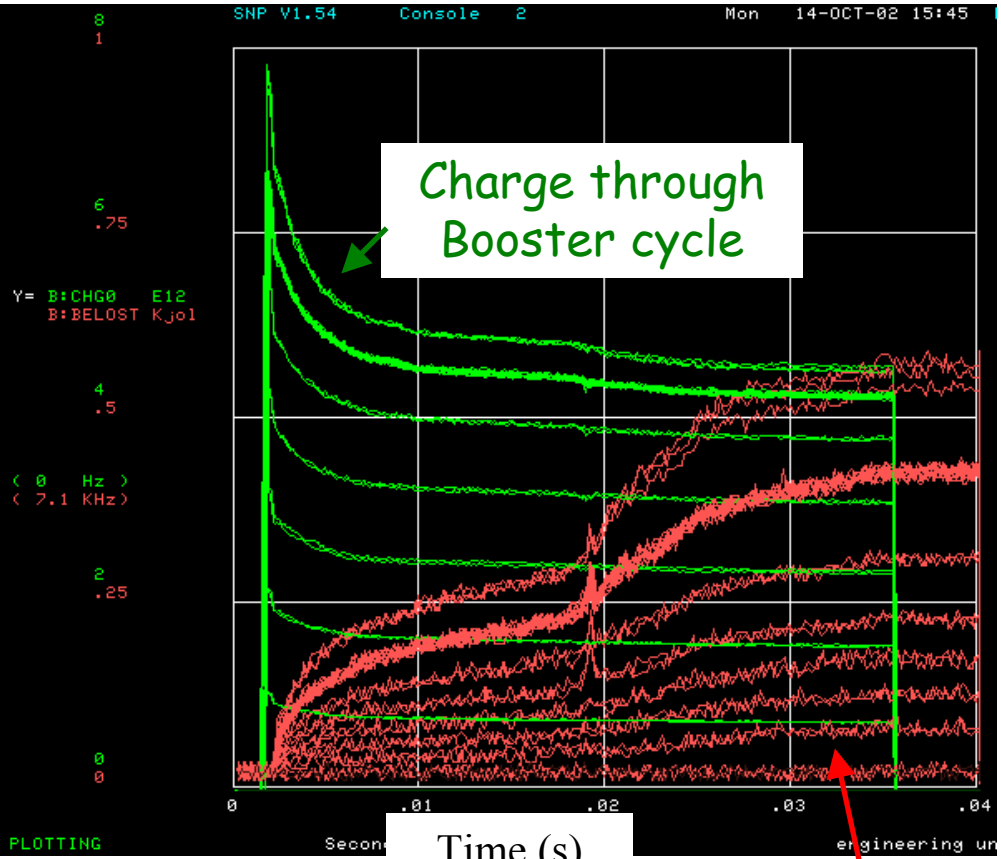
Energy Lost (W-min/p)

Record Performance

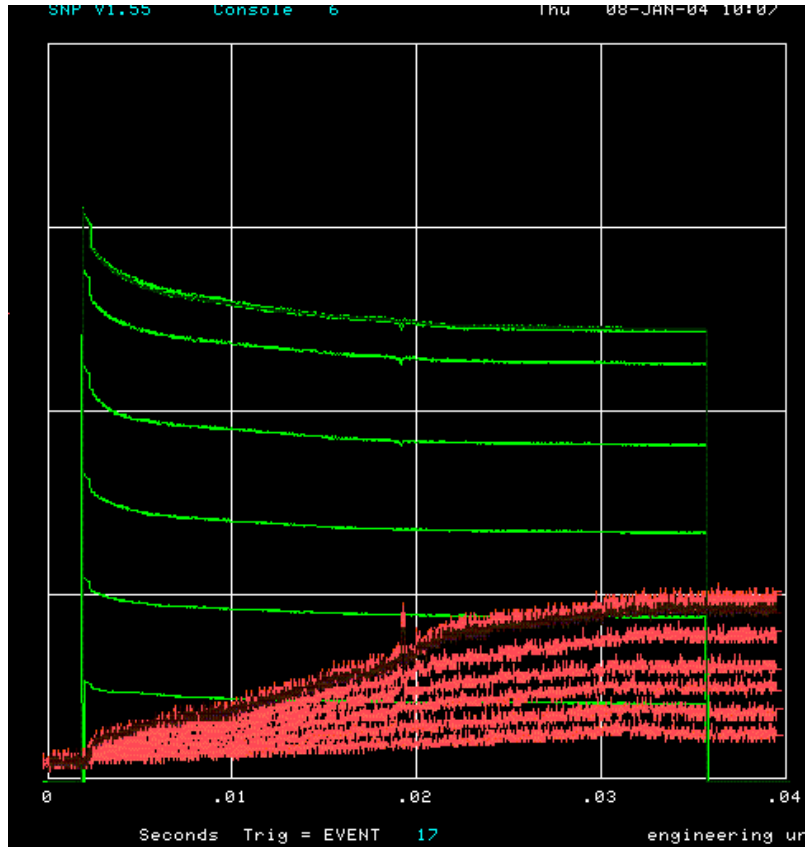
Several Unrelated Problems

How far have we come?

Before MiniBooNE



Now (same scale!!)

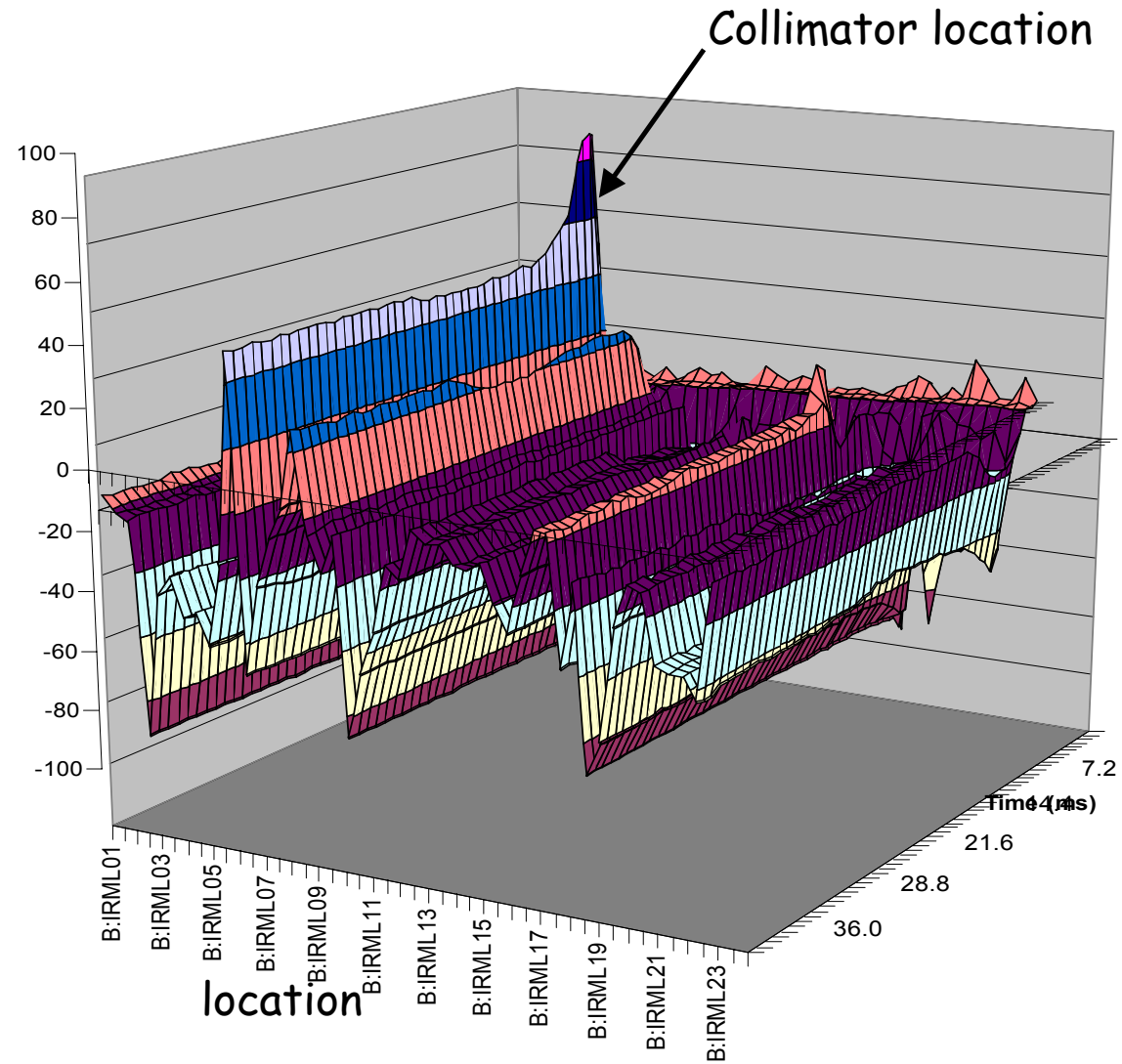


Note less pronounced injection and transition losses

Near Term Priorities (Booster)

- Optimizing Booster for improved lattice:
  - Tuning and characterizing 400 MeV line (Linac to Booster).
  - Tuning Booster orbit to minimize losses.
- Commission Collimators:
  - Estimate another month or so to bring into standard operation. (discussed shortly)
- Aperture Improvments:
  - Alignment (discussed shortly)
  - Orbit control
    - Abandoning our original global plan in favor of local control at problem spots for the time being.
  - Prototype RF Cavities
    - Two large aperture prototype cavities have been built, thanks to the help of MiniBooNE and NuMI universities.
    - We will install these as soon as they are ready to replace existing cavities which are highly activated.
- Multibatch timing: Beam cogging

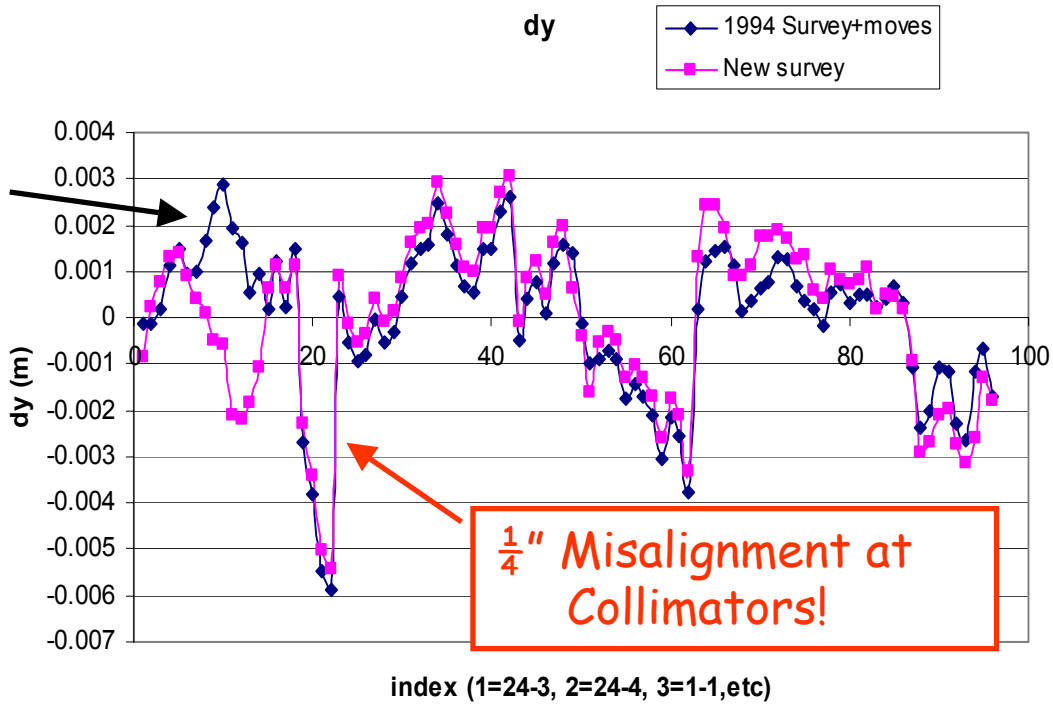
Collimator Studies



- Shown is the effect of putting in one of the secondary collimators as a percentage change in losses as a function of time around the ring.
- Studies are continuing.
  - "Rapid response team" will be put on problem.
- At present, primary collimators are not optimized to energy loss profile
  - Will replace in upcoming shutdown.

Alignment Problems

Effect of Booster tower shielding



- Working closely with AMG
- As opportunity allows
  - Fix vertical orbit
  - Align RF cavities
- Over the next year
  - Complete network
  - Integrate with MAD
  - Make a horizontal plan.

Priorities over the Next Year

- Linac Characterization and Reliability
  - Increase instrumentation of old linac to study instabilities.
  - Develop set of performance parameters.
- Booster improvements.
  - Prepare for modification of second extraction region
    - New septum
    - Modified dogleg magnets
    - On track for next year's shutdown.
  - Injection bump (ORBUMP) improvements:
    - Injection Bump (ORBUMP) Power Supply
      - Existing supply a reliability worry.
      - Limited to 7.5 Hz
      - Building new supply, capable of 15 Hz.
      - Aiming for summer shutdown (aggressive, but doable)
    - New ORBUMP Magnets
      - Existing magnets limited by heating to 7.5 Hz
      - Working on a design for cooled versions.
      - These, with a new power supply, will make the Booster capable of sustained 15 Hz operation.
      - Aiming for summer shutdown (aggressive, but doable).

Planning for the future

- In response to the "Finley Report", the lab management has asked for a "Proton Plan" for the proton source over the next few years, analogous to the Run II plan, but much lower in scope.
- The plan is to do what we can reasonably do to maximize the throughput and reliability of the existing proton source (incl. MI), under the assumption that a Proton Driver will eventually be built.
- Beyond the things I have already mentions, the scope is largely determined by the budgetary guidance:
  - FY04: $0-2M
  - FY05: $6M
  - FY06: $5M
  - FY07: $5M
  - FY08: $2.5M

Comment on the Budget

- This budget is more than enough to do the basic things that we must do to keep the proton source going, provided some of it appears this year!
- It *precludes* certain ideas that have been suggested:
  - New Linac front end, or any significant 200 MHz upgrade.
  - Decreasing the Main Injector ramp time
    - Which means there will be very little to do with the Main Injector.
- There are some "big" (>$1M) projects that must be discussed.

Large Projects Under Consideration

- Booster RF system:
  - Commission a design for a new booster RF system
  - Larger aperture, higher gradient cavities
  - Solid state distributed amplifiers
  - Goal to have design by January 2005.
  - Two year timescale to build and install (perhaps solid-state DA's can come sooner).
  - Cost ~all of it.
- Adding two additional cavities
  - Use university prototypes + spare parts
  - Cost ~$500K
- 30 Hz harmonic to booster ramp.
  - Effectively increases RF power
  - Cost of order $1-2M
- New LEL quad power supplies.
  - A significant reliability worry
  - Cost of order $1M.

Schedule for the Plan

- Will proceed with the vital projects for this year.
- Hope to have a skeleton of a plan by the end of this month.
- Will have a more detailed plan and major recommendations by this summer.

Expectation Management

- What we really think we can achieve:
  - Slipstacking to provide 1E13 protons per pulse for pbar production.
  - 5E20 protons to MiniBooNE by the time NuMI fully comes on in early 2005
  - 2-2.5E20 p/yr to NuMI in the first year of operation.
  - Increasing that over the next few years, to something over 3E20 p/yr.
- What we might achieve:
  - Continuing to operate the 8 GeV line at some significant level *after* NuMI comes on, ultimately delivering 1E21 protons to MiniBooNE and possibly supporting other experiments (e.g. FINESSE).
  - Delivering as many as 4E20 p/yr to NuMI, at which point things will be limited by Main Injector aperture and cycle time (with the present source, anyway).
- It would be unrealistic to believe:
  - We will ever send more than 4E20 p/yr to NuMI without significant (~$100M) investment in the existing complex.
  - That would be direct competition for resources with the current Proton Driver proposal.